Editorial

The Tower of Babel

AN INTERCHANGE OF IDEAS is necessary to social and technical progress. Hence language, which is the vehicle permitting this interchange, is an important part of our civilization. Some centuries ago, the people undertook a project called the Tower of Babel. This incurred the displeasure of the Lord who proclaimed: "Let us go down and there confound their language that they may not understand one another's speech." The project, therefore, failed of completion, for no longer could the workers cooperate toward a common goal.

Science, too, needs a common language easily understood, otherwise we risk failure in our purpose. Unfamiliar vocabularies built up in specialized fields are on the increase. But better understanding is not necessarily implicit. The resultant technical jargon often becomes a play on words, perpetuating hazy concepts or ideas long since outgrown, or serving no better purpose than to confound the public. Bricks are methodically laid on a Tower of Babel.

Willis R. Whitney once said that while science is as transparent as a goldfish bowl, it is hard to keep it clear because verbal fungi becloud it. Like a goldfish bowl, the language of science needs a periodic clean-up to allow clearer focusing on what is inside.

One way to improve the situation is to formulate and regularly revise a glossary of terms and definitions cutting across all engineering and scientific boundaries. The American Institute of Electrical Engineers has made an admirable start in this direction that might be profitably extended into other fields. Our Society has assumed the lead in the field of Corrosion through publication of the glossary of terms and definitions. Other Divisions should survey similar needs in an attempt to simplify and improve the terminology identified with their interests.

A second approach to the over-all problem is to continue missionary effort on the advantages of the metric system of weights and measures over the cumbersome English system. The waste and inefficiency resulting from using the dual systems continues to be a tremendous burden to society.

In our own field, we can seek to eliminate the ambiguity of sign for the electrochemical potential, and thereby remove another Tower of Babel whenever potentials are discussed. Cooperation of American chemists is especially needed to help erase the error of a second usage foisted on the scientific world some forty years ago.

These are but a few of the ways we can make our language one if we would proceed more directly to the problems at hand.

Fast Plating Can Be Quality Plating

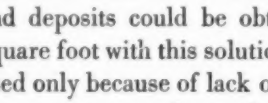
Conventional nickel plating practice is to operate at 50 to 75 amperes per square foot, although a few shops are operating at higher rates.

The question which confronts plating technicians is: What is the limiting current density at which sound nickel can be electrodeposited?

The Bayonne Research Laboratory of International Nickel has investigated both the theoretical and the practical aspects of this question.

Theoretical calculations give a limiting current density of 8400 amperes per square foot, using an all-nickel chloride solution with violent agitation. Practical results obtained under selected laboratory conditions indicated sound deposits could be obtained at 4260 amperes per square foot with this solution. This limitation was imposed only because of lack of equipment to produce a higher amperage at the available voltage. At a current density of 4260 amperes per square foot, a nickel deposit 0.001 inch thick is formed in 16 seconds.

This information was reported at the 1949 A.E.S. Annual Convention in a paper entitled, "Electrodeposition of Nickel at High Current Densities" by Wesley, Sellers and Roehl. Reprints of the paper as it appeared in the A.E.S. Proceedings (1949) are available on request.



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Technical Reviews

Adsorbed and Reaction-Product Films on Metals[1]

Herbert H. Uhlig[2]

With but few exceptions, all metallurgical operations are carried out in the atmosphere. As soon as metals leave the furnace, and in all subsequent treatment, they are exposed to a gas mixture of oxygen, nitrogen, moisture, CO_2, inert gases, and traces of other substances.

The continued presence of these gases can materially influence the properties of commercial metals. For example, a small amount of atmospheric nitrogen dissolved incidentally during melting of 18-8 stainless steel contributes toward making it nonmagnetic (1). Furthermore, in steel-making the reaction of the melt with moisture of the atmosphere forms hydrogen, which enters the metal and, if not subsequently removed, may cause later failure by cracking.

Atmospheric gases also influence behavior of metals in other ways. The small amounts of inorganic and organic sulfides indoors are difficult to detect by the usual chemical methods, yet if we expose a piece of silver or copper, the pronounced tarnish after a time shows conclusively that such traces are present. In the same way, but more obvious, the presence of oxygen in the atmosphere is associated with oxidation of metals at high temperatures, and with rusting of iron.

But the presence of the atmosphere exerts a still more subtle influence. Two pieces of metal, for example, if pressed together are easily pulled apart. No sensible form of attraction can be detected. Yet from fundamental considerations it is apparent that if we succeed in getting atoms of one piece in close enough proximity to atoms of the other, they will weld together. The lack of welding means, of course, that the fields of force exerted by metal atoms are rather short range. They extend, as a matter of fact, over a distance not much greater than an atomic diameter, or in the order of 10^{-8} cm. This observation indicates, furthermore, that there are substances on the surface of the metal which prevent the metal atoms from approaching each other to at least within an atomic diameter. These substances are usually gases of the atmosphere mentioned above, or their reaction products. Films of this kind insulate effectively the atoms of one metal piece from those of another, except under high pressures or high temperatures.

Wetting of Iron by Mercury

A simple experiment demonstrates the existence of such a film. If we take a piece of steel drill rod in the shape of a U and convert the end of it into so-called martensite by heating it to bright red and quenching it in water, the bend of the U is then brittle. If we immerse such a piece of steel into a tray of mercury and take it out again, nothing happens—the mercury immediately runs off the surface. This again is evidence that something is on the surface of the iron preventing mercury from coming within the field of force of the iron atoms. The substance on the surface gets there quickly, because if the U is first broken with a pair of pliers and immediately plunged into mercury the fracture shows the same lack of attraction for mercury as the rest of the surface. However, if we break the U *under* mercury, the fractured surface is now wet by the mercury, indicating that this time metal atoms were brought into close enough proximity of iron atoms to accomplish the analogy of cold welding.

What we observe is proof that gases of the atmosphere attach themselves rapidly to the surface of a metal such as iron, preventing close contact with mercury or other substances. The gases are said to be adsorbed. These adsorbed films on the surface of metals are common, and play an important part in the observed properties of metal surfaces.

Physical Adsorption and Chemisorption

We have come to recognize two kinds of adsorption. They are called physical adsorption, and chemisorption or activated adsorption. The properties of chemisorbed films overlap many properties of physically adsorbed films, and in boundary cases it is difficult to distinguish one type from the other. Yet, the classification into two kinds is both logical and convenient, since there are a sufficient number of clearly defined examples of each. The major differences in the two types of adsorption are as follows: First, *physical adsorption* may be reversible. If we apply a certain pressure of gas to a given area of metal, a definite amount of gas is adsorbed. If we increase the pressure, more gas is adsorbed, or if we decrease the pressure, some or all of the gas comes off again. Second, the amount of physically adsorbed gas decreases with rising temperature, so that at high temperatures relatively little if any gas adsorbs. The third consideration is that physical adsorption is general for all surfaces, taking place on glass, plastics, metals, or on wood. It is not specific for either the surface or the gas, and such adsorption as occurs is rapid. The forces of attraction are the Van der Waal forces, contrasted with exchange energy forces characterizing chemical bond formation. Accordingly, the heat of physical adsorption falls within the range of about 500 to 2000 calories per gram mole of adsorbed gas.

Langmuir (2) showed that physical adsorption could be represented by an equation of the type:

$$x = \frac{abp}{1 + ap}$$

where x is the amount of gas adsorbed per unit area of surface, a and b are

[1] Based on lectures at New York University Chapter of Sigma Xi, March 1948, and University Corrosion Conference, Chicago, June 1947.

[2] Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts.

constants, and p is the pressure. This equation traces the shape of the general adsorption isotherm for many gas-solid systems.

Brunauer, Emmett, and Teller (3) later made use of a modified adsorption isotherm to calculate from the amount of physically adsorbed gas, e.g., nitrogen, the true surface of a solid taking into account microscopic ridges, crevices, etc. By making appropriate assumptions regarding the pressure at which a monolayer of gas adsorbs on all contours of the solid, the surface is easily calculated from the average diameter of the gas molecule. The latter can be determined empirically by adsorbing the gas on glass or quartz beads which are examples of supercooled liquids having a microscopically smooth surface. This approach has been used successfully for surface determination of many different kinds of solids including metals. The method was used, for example, to estimate the true surface of acid-etched chromium (4), the values for which confirmed earlier reports of Bowden and Rideal (5) by another technique showing that an etched surface has an area as much as 50 times the apparent surface.

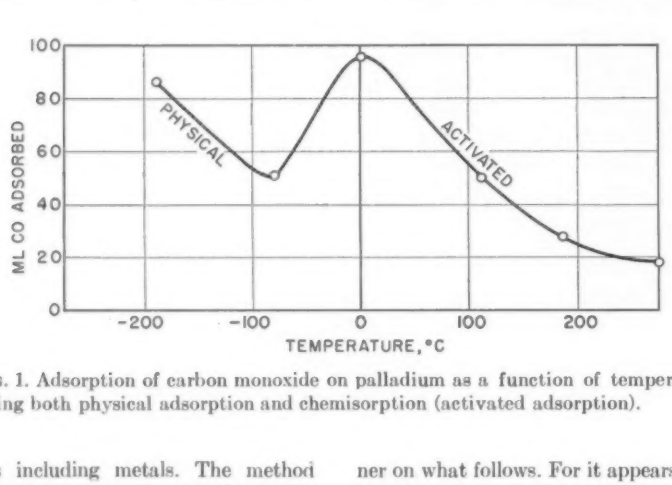

FIG. 1. Adsorption of carbon monoxide on palladium as a function of temperature showing both physical adsorption and chemisorption (activated adsorption).

Chemisorption, or activated adsorption, is characterized by an increase in amount of adsorbed gas on increase of temperature within certain ranges of temperature. This is quite the opposite of what one finds with physically adsorbed gas. A typical adsorption isobar showing both physical adsorption and activated adsorption of CO on palladium is illustrated in Fig. 1. Note that at high enough temperatures the amount of chemisorbed gas for this system also decreases with temperature.

Chemisorption, furthermore, unlike physical adsorption, is irreversible. Chemisorbed gas is not recovered by lowering the gas pressure. Furthermore, chemisorption is highly specific. It does not occur with all materials, nor with all gases. Oxygen on glass, or nitrogen on copper is not chemisorbed, whereas oxygen on tungsten is a typical example. In general, there must be strong chemical affinity of the adsorbing substance for the substance adsorbed. This conforms with a heat of adsorption considerably higher than is observed in physical adsorption, the values ranging from 10,000 to 100,000 calories per gram mole of adsorbing substance. Finally, chemisorption, like some chemical reactions, may be slow.

Chemisorption and Passivity

This general picture of physical adsorption contrasted with chemisorption introduces this discussion largely because it bears in an important manner on what follows. For it appears that chemisorption may be the key to the corrosion resistance of some metals chemically active in the emf series, like chromium or alloys of such metals (e.g., the stainless steels).

Langmuir in 1916 (6) first pointed out the nature of chemisorption and the properties that might be expected of a surface on which gases are chemisorbed. His work with tungsten, for example, showed that if oxygen were introduced into an evacuated system containing the metal, a certain amount of gas adsorbed on the metal surface. This was known because of several accompanying phenomena. First, electron emission from such a tungsten surface was less than 1/10,000 of its value for a clean surface, so that oxygen obviously had added to or altered the surface. A layer of negatively charged oxygen ions could account for this effect. Furthermore, the tungsten surface no longer catalyzed the dissociation of hydrogen molecules to hydrogen atoms at high temperatures, contrary to the behavior of clean tungsten. Oxygen had acted as a catalyst poison. Third, from kinetic considerations, Langmuir found that the calculated reaction rate of tungsten with O_2 molecules to form WO_3 agreed with experiment only by assuming the presence of oxygen *atoms* already on the surface. The surface substance was not tungsten oxide because the oxide volatilizes quite rapidly at 900°C, whereas this oxygen persisted on the metal surface at 1200°C. Furthermore, WO_3 is reduced by hydrogen at a temperature of 500°C, but the oxygen on tungsten did not react readily with hydrogen even at 1200°C. The conclusion one reaches, therefore, is that the surface oxygen reacted chemically with the tungsten, but the tungsten atoms remained in their lattice. This is equivalent to saying that the oxygen was chemisorbed. It is believed that oxygen *atoms* adsorb rather than molecules, not only because kinetic analysis of the oxidation rate mentioned above indicates this, but also because the heat of adsorption actually exceeds the heat of dissociation of oxygen (320,000 cal vs. 118,200 cal).

With residual metal forces satisfied by adsorbed oxygen, and oxygen valences satisfied in turn, the tungsten surface becomes less reactive. The reduced affinity applies not only for hydrogen, but for other environments as well. In other words, the tungsten becomes passive. Langmuir (7) suggested, although he did not investigate the matter further, that passivity of chromium must have its source in a similar mechanism.

Chromium and the Stainless Steels

This point of view, outlined below, has been carried over to the stainless steels and other alloys, and to the mechanism of passivators as a special class of corrosion inhibitors. Accordingly, if we expose a chromium surface to the atmosphere, oxygen—having affinity for the metal—adsorbs accompanied by a reduction in the chemical activity of the metal through satisfaction of surface valence forces. The metal, therefore, is less reactive than its position in the emf series suggests, and its potential in many solutions is more noble. According to a second and differing point of view, a protective Cr_2O_3 film forms, physically isolating the metal and making it corrosion resistant, or passive, by this mechanism.

It has been difficult so far to unequivocally differentiate one supposed mechanism from the other by a critical experiment, although the effort continues. At this stage of events, the evidence for an adsorbed film is based on the tungsten experiments of Langmuir and the logical tie-in with a host of related experiments, some of which are described later. This is the point of view favored by the writer (8).

It should not be inferred that oxygen is required for passivity. Many substances having affinity for chromium can act in the same manner. Chromates, for example, passivate chromium. The chromate ion with high affinity for the metal, in common with oxygen, is thought to adsorb on but not react with the metal in the orthodox sense of the word. The less active, or passive, chromium surface is again a matter of satisfied valence forces. This is probably the primary cause of passivity. A secondary effect may take place through slow formation of chemical compounds of chromium, such as Cr_2O_3, which adhere to the chromium surface and provide supplementary protection by interposing a diffusion barrier. Likewise passivity of stainless steels exposed to the atmosphere or of iron immersed in chromate solutions may be accompanied by slow formation of reaction-product compounds on the surface, but the primary and immediate source of passivity is thought to reside not in such compounds, but in adsorbed films of atoms or ions[3].

Chloride Ions and Pitting

By the same viewpoint, the action of chloride ions in destroying passivity is one of preferential adsorption. These ions also have affinity for the metal, and compete with oxygen or with chromates, or with any other passivating agent, for a place on the metal surface. In so doing, they may displace the adsorbed chromates or oxygen. However, the chloride ions do not remain adsorbed, because the metal-halogen reaction rate is high, or what is the same, the activation energy for reaction is low contrasted with corresponding activation energies for chromates or oxygen. The metal, therefore, is rapidly attacked at restricted areas where chlorides succeed in displacing the adsorbed passivator and where passivity breaks down. The result is pitting, often observed when passive metals corrode in presence of chlorides.

[3] Tammann was apparently the first to ascribe passivity in stainless steels to an adsorbed gas on the metal surface (9).

Action of Hydrogen

The action of cathodic hydrogen in destroying passivity has two possible interpretations. First, there may be direct reaction with, and reduction of, the adsorbed passivating substance. Alternatively, the hydrogen may adsorb preferentially on the metal surface, and in part enter the metal interstitially. As shown by experiments on hydrogen embrittlement, this process takes place readily with many metals. Within the metal, the electrons of dissociated hydrogen atoms are available to fill in vacant bands of energy levels, thereby altering the electronic structure of the metal and reducing its ability to chemisorb substances such as oxygen and other passivators. The relation between electron structure and chemisorption is discussed later.

Oxygen as Passivator

The mechanism of passivity based on satisfaction of surface valence forces applies to several metal systems, examples of which are the stainless steels and chromium exposed to air, and chromium or iron in contact with chromates as has been described. It also applies to the passivating effect of oxygen itself on iron immersed in aqueous media. For example, the corrosion rate of iron in natural waters first increases linearly with oxygen concentration. If, however, the partial pressure of oxygen is increased sufficiently beyond that of oxygen in the atmosphere, the rate of corrosion *decreases*. Data obtained by Groesbeck and Waldron (10) are shown in Fig. 2. Confirmation of these data has been obtained by Frese (11) and others.

We satisfied ourselves of the facts by sealing iron nails in a glass tube containing distilled water saturated with oxygen, and a similar tube under 30 psi of oxygen pressure. Under these conditions initial appearance of rust in these tubes was substantially delayed compared with similar nails immersed in aerated distilled water. The reason for the decrease in corrosion might be assumed to be a change in the nature of the protective oxide film on iron, but potential measurements indicate no reduction in solubility of the oxide, as is sometimes proposed as the reason for increased protection. As a matter of fact, potentials of iron in water containing high concentrations of dissolved oxygen are more noble than in aerated water by 0.6 to 0.8 volt (12). This is opposite in sign to the potential change one expects from decrease in solubility of an iron oxide and corresponding decrease in concentration of ferrous ions. On the other hand, if oxygen at high concentrations is adsorbed on the metal surface, producing the same inert surface as was shown for tungsten, and which was indicated above for chromium and stainless steels, the more noble potential is evidence of similar passivity.

The explanation based on adsorption accounts also for the observed decrease in corrosion of iron in moving aerated water. As the water velocity is raised, the corrosion rate first *increases* because more oxygen reaches the surface. The stagnant liquid film on the iron surface, acting as a diffusion barrier, is reduced in thickness by motion of the water. However, if the velocity is still further

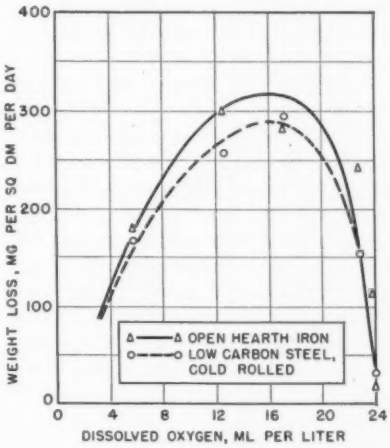

FIG. 2. Effect of dissolved oxygen on corrosion of iron and steel at velocity of 15 ft/min, 30°C. 48-hour test. (Groesbeck and Waldron).

increased, it is found that a maximum corrosion rate is reached; thereafter the rate *diminishes*. At this point, oxygen presumably reaches the surface more rapidly than it is consumed by depolarization, so that some adsorption takes place. This adsorption again produces passivity and decreases the corrosion rate. Initiation of passivity is indicated by a potential for iron in moving water 0.4 volt more noble than in stagnant water (13). Of course, if the velocity is increased still more, mechanical effects of erosion then enter and the corrosion rate again goes up.

Adsorption versus Reaction

What determines whether a molecule like oxygen adsorbs or reacts? In other

words, when is there an activation energy for oxide formation with accompanying slow rate of reaction preceeded by adsorption, and when is the activation energy zero with high reaction rate and no preliminary adsorption? This is actually a complicated question, but a first approximation to an answer is possible. If we expose a piece of clean copper, oxygen reacts rapidly to form copper oxide as shown by electron diffraction measurements (14). The oxygen succeeds in pulling copper atoms from the metal lattice to form the Cu_2O lattice. From the rapidity of initial oxide formation, it appears reasonable that there is no appreciable activation energy for the reaction at room temperature. Although an oxide forms, the metal, nevertheless, is not passive insofar as the galvanic potential does not become more noble, nor is the corrosion rate altered appreciably. On the other hand, if we similarly expose a piece of chromium, an oxide is not detectable by electron diffraction techniques even though the chromium is exposed to air for several days and the metal is passive, as indicated by a noble potential and very low corrosion rate (15). An activation energy for reaction apparently is associated with this system because on raising the temperature sufficiently, an oxide can be detected (incidentally, with no appreciable effect on the corrosion rate or potential in aqueous media). It is reasonable to suppose, therefore, that until reaction occurs accompanied by displacement of chromium atoms from their lattice, the oxygen remains adsorbed. This accounts for initial absence of an oxide diffraction pattern. Furthermore, oxygen is adsorbed probably as the negative ion (one or more extra electrons per atom) in view of recent contact potential data and because the oxygen ion is presumably adsorbed on tungsten. Whether oxygen reacts or adsorbs, therefore, depends, in part, on whether it is easier for an electron to leave the metal (forming adsorbed oxygen ion) or for the metal atom to leave its lattice (forming metal oxide). The ratio of the energies expressing either event should be an approximate index, consequently, of whether metals become passive on exposure to the air (adsorbed films), or are incapable of becoming passive in the same sense (oxide layers) because of rapid reaction. This ratio is given by the work function (energy to remove an electron from a metal) divided by the heat of sublimation for the metal. If the ratio of energies in, e.g. electron volts, is greater than unity, it is easier for the metal to leave the lattice, and oxidation is the rule. If the ratio is less than unity, it is easier for an electron to leave the metal, a situation favoring adsorption of oxygen and accompanying passivity. A calculation of this ratio for several metals indeed bears out that many metals usually considered not passive under normal conditions, such as sodium, calcium, and copper, have ratios greater than one; whereas metals usually considered passive, such as chromium, tungsten, and nickel, have ratios approximately equal to or less than one (Table I).

TABLE I. *Ratios of work function to heat of sublimation for various metals*

	Heat of Sublimation, ΔH_s, 25°C, electron-volts	Work Function, electron-volts	Ratio, Work Function $/\Delta H_s$
K	0.93	2.24	2.4
Na	1.12	2.37	2.1
Ca	1.85	3.09	1.7
Mg	1.56	3.60	2.3
Zn	1.35	3.7–4.2	2.7–3.1
Hg	0.63	4.50	7.1
Pb	2.01	3.8	1.9
Al	2.92	3.6–4.4	1.2–1.5
Ag	3.0	3.9–4.7	1.3–1.6
Cu	3.54	4.80	1.36
Mn	3.02	3.76	1.25
Pt	5.40	6.3	1.17
Ni	4.26	4.1–5.0	0.96–1.2
Fe	4.20	4.2–4.7	1.0–1.1
Cr	3.87	4.35	1.1
W	8.8	4.52	0.51
Mo	6.75	4.12	0.61
C	8.6	4.82	0.56

In looking over the tabulation of these ratios, iron seems to be out of place with a ratio of 1.0 to 1.1 corresponding to passivity. It must be remembered, however, that iron is passive in dry oxygen, reacting rapidly only when in simultaneous contact with liquid water. The action of moisture in accelerating the reaction may owe to the possibility of depolarization at cathodic areas and ease of ion hydration and solution at the anode areas. These factors reduce the activation energy with which the iron ion enters the aqueous phase, compared with a higher activation energy required to enter an iron oxide phase. With chromium, on the other hand, the metal ions resist hydration and solution as well as oxide formation. Significantly, chromium as anode in many aqueous media (e.g., Na_2SO_4 solution) forms hydrated ions with considerably more difficulty than does iron, as gaged by the impressed potential necessary to affect dissolution. Actually, when chromium atoms leave a chromium anode in Na_2SO_4 solution, they do so as chromate ions (CrO_4^{--}) rather than as chromium ions (Cr^{+++}), whereas iron corrodes generally as Fe^{++}.

Platinum with a ratio of 1.17 is on the border. Since it is a noble metal with but little affinity for oxygen, there may be relatively little tendency either for chemisorption or oxidation, although both take place to some extent. Silver, also noble, does not oxidize in air, although were there sufficient affinity for oxygen, the ratio of 1.3 to 1.6 indicates that it would oxidize rapidly with zero activation energy.

It is noteworthy that the metals usually exhibiting passivity are those in the transition groups of the periodic table as classified by Niels Bohr. (Transition metals are those with unfilled *d* electron energy levels. The first period includes metals from Sc through Ni, the second period, Y through Rh, etc.) These are the metals considered favorably disposed toward passivity by the electron configuration theory of passivity (16) and which enter as major components of corrosion-resistant alloys. They are also the metals of Table I with properties favorable to chemisorption. Manganese is perhaps an exception; this metal has other unusual properties as compared with its neighbors in the periodic system. Moreover, work-function data for many of the metals are not known precisely. This accounts for the range of values reported

in Table I, as well as for the possibility that the manganese value is high.

Adsorption of Metals on Metals

Not only do nonmetals adsorb on metals, but also metals adsorb on metals, as indicated in the experiment in which iron was fractured in mercury without access to air. A few other instances have been studied, for example, the work of Langmuir on electron emission from tungsten surfaces. In one experiment, caesium was admitted into an evacuated glass vessel containing a tungsten wire. The caesium evaporated at room temperature and condensed onto the tungsten wire even though the wire was at a temperature 400°C higher. This indicated appreciable attraction between tungsten and caesium. That the caesium had adsorbed on the tungsten could be verified easily by the accompanying electron emission which was considerably higher than for pure tungsten. The increased emission, indicating a lower work function for the caesium-tungsten surface and a positive charge on the metal surface, plus the fact that caesium evaporated from tungsten as the positive ion, made it appear plausible that caesium adsorbs on tungsten as the positive ion, or that caesium donates possibly one electron per atom to tungsten. Hence, the ability of tungsten to adsorb caesium is plausibly related to the energy of taking up an electron, which is measured by the work function of tungsten (4.5 electron volts, or loosely 4.5 volts). On thoriated tungsten, for example, (tungsten covered with an atomic layer of thorium) having a work function of only 2.9 volts, caesium does not adsorb. In other words, it is necessary that the affinity of tungsten for electrons be sufficient to extract the valence electron of caesium before adsorption can occur.

One can estimate, using the reasoning described before, that caesium adsorbed on tungsten has chemical properties significantly distinguishable from caesium metal. The work functions for caesium and for caesium on tungsten are 1.81 and 0.72 volt, respectively, whereas sublimation energies for caesium, and for caesium on tungsten, are 0.53 and 1.77 electron volts. It follows, therefore, that caesium with ratio of work function to heat of sublimation greater than unity (1.81/0.53) should oxidize immediately on exposure to air, whereas caesium on tungsten, with ratio less than unity (0.72/1.77), should adsorb oxygen instead and oxidize only slowly.

Iron Adsorbed on Chromium, Passivity in Stainless Steels

The theory, in short, leads to the prediction that if a metal is adsorbed on another, change in chemical properties of the adsorbed metal can be expected. This prediction led to an interesting experiment verifying that such is the case (17) and which tied in with the electron configuration theory of passivity in the stainless steels. The latter theory points out that on alloying chromium with iron, electron interaction takes place between the components, with the result that the alloy assumes the passive properties of chromium at the observed critical minimum concentration of about 12 to 15 weight per cent chromium. This critical concentration is estimated approximately from the electron configuration of the constituent metal atoms. The important part of the theory from the standpoint of this discussion is the prediction that merely bringing a piece of chromium into physical contact with a piece of iron should impart passivity to iron at the interface.

As indicated before, it is not easy to bring one metal into close physical contact with a second, other than by alloying, but it can be done by starting with uncontaminated surfaces, free of adsorbed gases. One way is to evaporate iron on hydrogen-reduced chromium, or a second way is to electrodeposit iron on pickled chromium. We used both methods. This gave a composite metal essentially of chromium covered by a relatively thick layer of iron. The composite metal was then immersed in 3*N* nitric acid for fifteen minutes. This treatment removed all active iron within about one minute, as was shown by immersing a specimen of copper similarly covered by iron. According to the above theory, there should be a passive layer of adsorbed iron remaining, made so by physical contact with the chromium and hence resistant to nitric acid. To detect such a layer after nitric acid treatment, the chromium surface was washed with 1.5*N* hydrochloric acid, and the solution analyzed for iron. After this first wash, a second with hydrochloric acid was used as a blank to correct for any source of iron from the chromium or the reagents. Significantly, it was found in all cases that there was definite *residual iron adsorbed* on the chromium. Based on true chromium surface, as determined using the Emmett-Brunauer-Teller method of surface measurement, it appeared that the adsorbed iron remaining after nitric acid reaction was in the order of a monolayer. This confirmed the theory and indicated that the mechanism of passivity in stainless steels is related to electron interaction between iron and chromium.

What is a possible mechanism for increased corrosion resistance attending electron interaction? The aforementioned ratios of work function to heat of sublimation contribute one possible picture. It is probable that adsorption of iron on chromium increases the sublimation energy so that iron has less tendency to leave a chromium surface than an iron surface. This is known from the marked tendency of iron to diffuse over the surface of chromium in the residual-iron experiments mentioned above. It is also reasonable that adsorbed iron on chromium may lower the work function as does caesium on tungsten. Finally, electron interaction may induce in iron a reluctance to form hydrated ions, typical of chromium. Further fundamental data are needed to find out which factor is most important.

What can be said with some assurance is that the specific electron configuration of a metal or alloy enters significantly into the conditions that establish the corrosion rate or oxidation rate, and that it also enters the conditions establishing passivity[4].

The Two Kinds of Passivity

If the foregoing reasoning is correct, there are, therefore, two kinds of passivity. One results from physical isolation of the metal from its environment by interposition of a relatively thick reaction-product film (physical passivity). The other results from a single atomic or ionic film chemisorbed on the metal surface (chemical passivity). Examples of physical passivity are lead sulfate on lead, or magnesium oxide on magnesium. On the other hand, examples of chemical passivity are monolayers of carbon monoxide or oxygen on 18-8 stainless steels, or chromate ions on iron.

Chemical passivity is confined largely to the transition metals of the periodic

[4] Recently it was shown that the change in electron configuration of the Cr-Fe alloys at the Curie temperatures is accompanied by change in activation energy for oxidation in O_2 (18). Tammann and Siebel earlier showed this same effect for the Fe-Ni alloy system (19).

table, although physical passivity may also enter to supplement chemical passivity (e.g., simultaneously adsorbed oxygen and hydrous FeO on iron account for both kinds of passivity). Physical passivity alone is confined largely to the nontransition metals. Chemical passivity appears to be responsible for the major corrosion resistance of the stainless steels and chromium, and appears also as the important factor in explaining corrosion resistance of metals and alloys such as nickel, molybdenum, titanium, zirconium, the Monels, the Hastelloys, and the Stellites. A film on these metals accompanying their passivity and high corrosion resistance need only be a monolayer, since satisfaction of residual valence forces occurs within the order of atomic dimensions.

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Formamide Hydrochloride

George-Maria Schwab[1]

In 1910 Roehler[2] described a hydrochloride of formamide, crystallizing with slight production of heat on passing dry hydrogen chloride gas through liquid formamide for half an hour. Based on analyses of the chlorine content (observed: 68.6%, calculated: 69%) he ascribed to it the formula of an acidic salt $HCONH_2Cl \cdot 2HCl$. Conductivity measurements in pure formamide gave $\Lambda_\infty = 89$.

This salt should act as an acid analog in formamide as solvent and should depress conductivity if added to the corresponding base analog, sodium formamidate.

Therefore, the "hydrochloride" was prepared in this laboratory by a modified method, adding aqueous concentrated hydrochloric acid to cooled formamide and precipitating with acetone. Volumetric analysis with NaOH or $AgNO_3$ gave a chlorine content of 70 per cent. However, in formamide as solvent, conductivity of this salt added to sodium formamidates, prepared in two ways did not deviate from additive conductivity.

The doubts, thus resulting, as to the nature of the "hydrochloride" are increased by the fact that ammonium chloride has almost the same chlorine content of 66.4 per cent. In fact, it was found that the salt prepared by Roehler's method as well as by that described above gave exclusively the x-ray pattern of cubic body-centered ammonium chloride, and, hence, is essentially ammonium chloride. This must have been formed according to:

$$HCONH_2 + HCl \rightarrow NH_4Cl + CO$$

or $$HCONH_2 + HCl + H_2O \rightarrow NH_4Cl + HCOOH.$$

Thus, Roehler's statement is in error, and a formamide hydrochloride does not exist, apparently because the basic function of the amido group is overshadowed by the neighboring carbonyl group.

I would like to thank Dr. W. J. Hamer of the U. S. National Bureau of Standards for his fruitful discussion.

[1] Department of Inorganic, Physical, and Catalytic Chemistry of the Institute "Nicolaos Canellopoulos," Piraeus, Greece.

[2] H. Roehler, *Z. Elektrochem.*, **16**, 419 (1910).

Ninety-ninth Meeting of the Electrochemical Society

Washington, D. C., April 8, 9, 10, and 11, 1951

Sessions on

Electronics, Electrothermics, Electric Insulation, Luminescence,

Rare Metals, and Theoretical Electrochemistry

Round Table on Industrial Electrolytics

Headquarters at the Wardman Park Hotel

Current Affairs

Candidates for Office—1951-52

Ralph M. Hunter

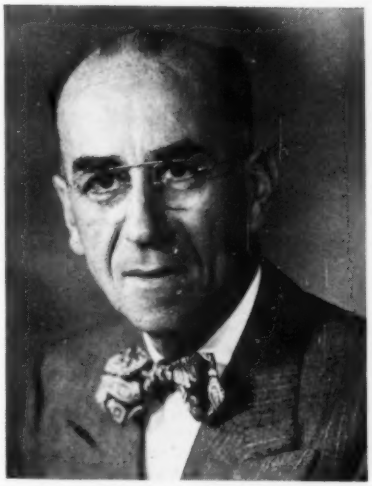
Presidential Candidate

Ralph Maurice Hunter, Manager of the Electrochemical Division of The Dow Chemical Company, Midland, Michigan, has served as a Vice-President of The Electrochemical Society for the past three years. Dr. Hunter has been a member of the Society since 1922 and has been on many important committees in recent years. He has been Vice-Chairman and Chairman of the Industrial Electrolytic Division, member of the Acheson Medal and Perkin Medal Award Committees, served on the Board of Directors, and was Chairman of the Ways and Means Committee. He is at present a member of the latter Committee.

Born in Philadelphia, Pennsylvania, August 18, 1896, Ralph Hunter received the B.S. degree in Chemical Engineering from Case Institute of Technology in 1918, and honorary degree of Doctor of Engineering in 1950. He became associated with The Dow Chemical Company in 1918 and now manages the electrochemical division, is Director and President of the Midland Ammonia Company, and Director of Dow Chemical of Canada, Ltd.

At the close of World War II he was a member of the Technical Industrial Intelligence Committee investigating and reporting on the German electrochemical industry, specializing in magnesium and alkali chloiine.

Mr. Hunter is a member of the American Chemical Society, American Institute of Chemical Engineers, Sigma Xi, and National Association of Corrosion Engineers.



RALPH M. HUNTER

JESSE E. STARECK

JOHN F. GALL

MARVIN J. UDY

John F. Gall

Vice-Presidential Candidate

John F. Gall was born in Chicago, Illinois, April 15, 1913. He received his B.S. degree in chemistry from Northwestern University in 1934 and the Ph.D. in physical chemistry from the University of Chicago in 1939. During his graduate years at the University of Chicago he was successively a University Fellow and a faculty assistant.

He started work with the Pennsylvania Salt Manufacturing Company in December of 1938 as a physical chemist in the Research and Development Department. He was successively Group Leader in electrochemical research, Assistant Research Supervisor, and is now Supervisor of the Research Department at Pennsalt's Whitemarsh Research Laboratory. His experience here has given him a specialized knowledge of electrolytic chlorine-caustic manufacture, peroxygen compounds, chlorates, electrolytic cleaning of metals, electropolishing and electroplating. He is an authority in the field of fluorine production and fluorination reactions.

Dr. Gall became a member of The Electrochemical Society in 1941. He was Chairman of the Theoretical

Electrochemistry Division from 1946 to 1948, and of the Electric Insulation Division in 1949 and 1950. He has been active in the local section affairs at Philadelphia and is Vice-Chairman of the Philadelphia Section.

He is a member and officer of the American Chemical Society and a member of the AAAS.

Jesse E. Stareck

Vice-Presidential Candidate

Jesse E. Stareck, Director of Research for United Chromium Incorporated, Detroit, was born in 1905 in Petersburg, Michigan. He is a graduate of the University of Kansas, from which he also received the M.A. and Ph.D. degrees. While working for his doctorate, Dr. Stareck discovered the method for color plating, later known as Electrocolor. In 1933 he was awarded the Roy Cross Research Fellowship to further his studies in color plating. The next year he joined the staff of the Kansas City Testing Laboratories where he worked on the commercial development of the color-plating process.

In 1935 he came to the research staff of United Chromium Incorporated where he has been ever since, first at Waterbury, Connecticut, and at present in the Detroit Laboratories. He has made important contributions to electroplating processes, protective coatings, and the theory of corrosion. Some of the better known processes are Electrocolor, Patternplate, copper plating from pyrophosphate solutions, and high-speed chromium plating.

Dr. Stareck is a member of many technical societies and has held office in the Detroit Section of The Electrochemical Society and has been a representative of the Local Section Advisory Committee. He is a member of the Detroit Branch of the American Electroplaters' Society, the American Chemical Society, Electrodepositors' Technical Society, and is chairman of a subcommittee of the American Society for Testing Materials.

Marvin J. Udy

Vice-Presidential Candidate

Marvin J. Udy, Consultant in metallurgical and electrochemical engineering, is a native of Utah and a graduate of the University of Utah, class of 1915. The next year he received the M.S. degree from the same school and, in the two years following, was assistant research chemist at the U.S. Mining and Smelting Corporation in Utah.

Coming east, Mr. Udy joined the Hooker Electrochemical Company and later became chief chemist and research engineer of the Haynes Stellite Company. While there he developed a process for cadmium plating, the patents for which formed the basis of the Udylite Process Company, now of Detroit. Mr. Udy was with the Electrometallurgical Company of Niagara Falls for a period of eleven years and in 1931 he joined the staff of the Swann Chemical Company of Alabama and later became research and development engineer for Oldbury Electrochemical Company.

Since 1937 Mr. Udy has been consulting engineer for the Chromium Mining and Smelting Company, developing a process for treating low-grade chrome ores. He is, at present, consultant for this company, the New Jersey Zinc Company, the Vanadium Corporation of America, and for some South American metallurgical concerns. He makes his home in Niagara Falls.

Mr. Udy was the recipient of the Schoellkoff Medal in 1948. He has been a member of The Electrochemical Society since 1919 serving for three years as Manager, also as Vice-Chairman and now as Chairman of the Niagara Falls Section. He was General Chairman for the 1950 convention at Buffalo.

Symposium on Electrode Kinetics

The Theoretical Division announces a symposium on "Electrode Kinetics" for the Spring Meeting at Washington, D.C., April 8–11, 1951. Subjects to be discussed include overvoltage, polarization, electrode reaction mechanisms, theory of potentials, etc. Tentative titles of papers received so far include the following:

1. "General equations and important parameters of electrode kinetics"
2. "Influence of inhibitors on the transfer of ions and electrons to iron in acids"
3. "Researches on the electrochemical behavior of metals"
4. "Kinetics and thermodynamics of electrolytic deposits less than monolayers"

In addition to papers from scientists in this country, there will be contributions by scientists from England, France, Italy, and Germany.

The symposium promises to be one of the most important of those sponsored by the Division in recent years, and will be of major interest to everyone concerned with the scientific frontiers of electrochemistry. The full program will be announced in a later issue of the JOURNAL.

Inquiries should be addressed to H. H. Uhlig, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts.

New Hooker-Detrex Plant

A large, modern trichlorethylene manufacturing plant has been completed by Hooker-Detrex Incorporated, at Ashtabula, Ohio. The new plant will produce Perm-A-Clor and Triad metal degreasing solvents for the Detrex Corporation, Detroit, Michigan. The solvents are available for both industrial cleaning and oil-extraction processes.

The latest developments in production techniques and equipment have been installed and it is expected that full production capacity will be reached by November 1, 1950. Works manager for the new plant is H. D. McKinley.

Miniature Tube Plant for RCA in Cincinnati

The RCA Victor Division of the Radio Corporation of America has acquired a new plant for the manufacture of miniature-type electron receiving tubes.

The plant was purchased from the Rich Ladder and Manufacturing Company and is scheduled to be in full production by the fall of 1951. The miniature tubes, first developed for use in pocket-sized radio sets, are now widely used throughout the radio-electronics field, and the new plant is designed to meet the needs of the expanding industry.

A.S.T.M. Publications Now Available

The American Society for Testing Materials has announced two new publications: "Data on Corrosion- and Heat-Resistant Steels and Alloys—Wrought and Cast" and "Symposium on Evaluation Tests for Stainless Steels."

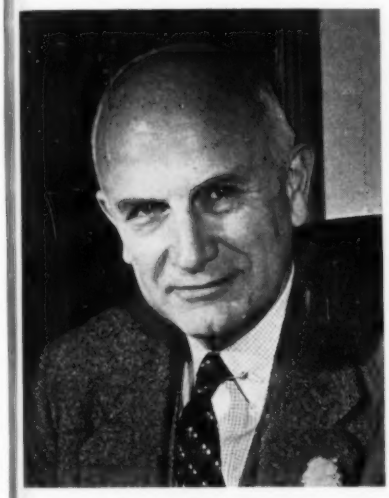
In the first, new data and tables bring previous compilations up to date and a new section on cast alloys is included. Data is condensed to simple form and applies to stainless steels in wide commercial use. The second book presents an appraisal of some of the testing methods for stainless steel alloys now in use.

Both books may be procured from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., for $2.50 each.

100th Anniversary for Pennsylvania Salt

The Pennsylvania Salt Manufacturing Company reached its 100th anniversary on September 25th and marked the occasion throughout the following week by holding a series of special events to honor all those who have contributed to its success, from the founders to the present large personnel. The centennial celebration was held at the Whitemarsh Laboratories at Chestnut Hill, near Philadelphia.

Highlighted events were: Monday luncheon for shareholders, with the Governor of Pennsylvania, James H. Duff, as speaker; Tuesday evening



GEORGE B. BEITZELL

dinner party for all employees of plants at Easton and Cornwell Heights, and retired employees; Wednesday luncheon for Pennsalt's business friends with company president George B. Beitzell as speaker; Thursday and Friday, the first meeting of the company's entire sales force ending with a dinner party for the members and their wives.

The company is one of the oldest chemical companies in the United States. It has played a long and active role in the growth of America's chemical industry and, today, is one of the leading manufacturers of basic chemicals, producing $38,000,000 worth of products a year, for nearly every industry in the country. This output includes more than 300 different items, ranging in package-size from four-ounce bottles of bactericide to 75-ton tank cars of acids.

The company was founded 100 years ago by five young Philadelphia Quakers who bought a patent for making alkalies from salt, raised $100,000 among themselves and a dozen friends, and purchased a plant site over salt deposits near Pittsburgh. They were George T. Lewis and his brother-in-law, Samuel F. Fisher, Charles Lennig, a chemical manufacturer, George Carson, and Samuel Simes. Lennig was Pennsalt's first president.

The first plant was built at East Tarentum, now Latrona; its principal product was to be caustic soda and the new company's markets to be the growing Midwest cities. Their first process failed and the losses nearly wiped out the original investment. A product which would make a quick profit had to be found. Lewis thought of household-sized packages of lye for home soap making. It proved an instant success.

In the years following, the company used its profits to increase equipment, improve the process, and add new products. Soon the company entered other fields. In the 1860's the refining of petroleum to supply kerosene for home lighting was begun. In 1964 Pennsalt made an agreement with the Danes to import cryolite from Ivigtut, Greenland, and they have imported this material ever since. From cryolite the company obtained alum, a product used in the iron and steel industry, and later it was the electrolyte used for producing aluminum, in making insecticides, as a flux, and in the manufacture of abrasives.

Pennsalt's second plant was built at Green Point in Philadelphia in 1872. In the 1890's came the electrolyte plant at Wyandotte, Michigan, for the production of caustic soda. In connection with this, the company acquired the Gibbs diaphragm cell, invented by Arthur E. Gibbs, which contributed greatly to the method of producing caustic soda and chlorine.

Another notable event in the expansion of the company came about when the Goldschmidt Detinning Company of New Jersey became the first large user of Pennsalt's chlorine. Pennsalt's later developments included the Tacoma Electrochemical Company, serving the pulp and paper industry; The General Laboratories, Inc., of Madison, Wisconsin, supplying products for dairy sanitation; Sterling Products Company at Easton, Pennsylvania, producing laundry and dry cleaning products; and later, chemicals for agricultural uses.

PERSONALS

G. H. KISSIN has terminated his connection with Physical Science Associates of Berkeley, California, and has joined the staff of the Division of Metallurgical Research of Kaiser Aluminum and Chemical Corporation at Spokane, Washington.

DAVID H. KENNY, the first member of the Society to notify us of his induction into the Armed Forces, has now left the General Motors Research Laboratories, Detroit. His address for the present is Lake Linden, Michigan.

CHARLES H. ORR has accepted a position as assistant instructor in the Chemistry Department at Syracuse University, Syracuse, New York. Mr. Orr was formerly in the Chemistry Department at Ohio State University.

H. A. DOERNER has been made Chief, Metallurgical Division, Region III (California and Nevada) of the Bureau of Mines, with headquarters at the U. S. Appraisors Building, San Francisco. His work will include the metallurgical research in the laboratories at Reno and Boulder City, Nevada, and Berkeley and Redding, California. Mr. Doerner was previously with the Bureau at Albany, Oregon.

HUGO A. BARBIAN has left the Battery Research Department of Olin Industries at New Haven, Connecticut, to join the Technical Service and Development Department of the Magnesium Division of The Dow Chemical Company at Midland, Michigan. Mr. Barbian will be working on corrosion problems on magnesium. Before joining Olin Industries he was employed by Dow in the Magnesium Division.

JOHN JOHNSTON

Dr. John Johnston, retired director of research for the United States Steel Corporation, died at Bar Harbor, Maine, on September 12th. He was 69 years old.

Dr. Johnston, who was a Past President of The Electrochemical Society, devoted most of his life to metallurgical research. He began his professional career in 1908, serving for eight years on the staff of the Geophysical Laboratory of the Carnegie Institute of Washington, and later was with the American Zinc-Lead and Smelting Company, the United States Bureau of Mines, and the National Research Council.

From 1919 to 1927, Dr. Johnston was Sterling Professor of Chemistry at Yale

University. He then became director of research for United States Steel which post he held until his retirement in 1946.

Born in Perth, Scotland, Dr. Johnston held B.Sc. and D.Sc. degrees from St. Andrew's University in Dundee, and studied at the University of Breslau, Germany. He received honorary degrees from Yale, Lehigh, and New York Universities. He was a member of The Electrochemical Society, Franklin Institute, American Chemical Society, Philosophical Society of America, British Iron and Steel Institute, Faraday Society, Institute of Metals, the Chemists Club, and the Century Association.

LEONARD G. VANDE BOGART

Leonard G. Vande Bogart, for 27 years a Corrosion Engineer for the Crane Company, Chicago, died on September 10 at his home in that city.

Mr. Vande Bogart was a member of The Electrochemical Society and was one of the charter members of the Corrosion Division, having served as its first Chairman in 1942, and also served on the Editorial Advisory Board of the *Corrosion Handbook*. He was the author of many technical papers and the book, "Combating Corrosion in Industrial Process Piping."

He was born in Sheboygan Falls, Wisconsin in 1892.

JOHN C. SOUTHARD

Dr. John C. Southard, Director of Research for Solar Aircraft Company, San Diego, California, died September 4th at the age of 43.

Previous to his work at Solar, Dr. Southard was chief process metallurgist for Titanium Alloy Manufacturing Company, Niagara Falls, and also was with the U. S. Department of Agriculture and the U. S. Bureau of Mines.

Dr. Southard was actively associated with The Electrochemical Society, the American Chemical Society, ASM, AIME, and other scientific organizations. He was the author of some 18 technical papers.

M. F. COOLBAUGH

Dr. M. F. Coolbaugh, 73, of Golden, Colorado, president emeritus of the Colorado School of Mines and a nationally known consulting engineer and educator, died on September 9th of a heart attack.

Dr. Coolbaugh was active in scientific work during both world wars, and held several state and federal appointments during his career. As a teacher he was chemistry instructor at Colorado College, Columbia University, South Dakota School of Mines, Case School, and Colorado School of Mines. He was Mines president from 1925 to 1946.

He was born in Coolbaugh, Pennsylvania, named for his forbears.

Dr. Coolbaugh was a longtime member of The Electrochemical Society and held memberships and offices in a number of scientific societies and honorary fraternities.

NEW MEMBERS

In September, 1950, the following were elected to membership in The Electrochemical Society:

Active Members

MATTHEW E. CARLISLE, Martin and Carlisle Chemical Laboratory, Inc., mailing add: 1500 North Fourth Street, Albuquerque, New Mexico (Corrosion and Electrodeposition)

JOHN S. DEWAR, National Carbon Limited, 805 Davenport Road, Toronto 4, Ontario (Electrothermic)

GEORGE NEWMAN, The Electrolizing Corporation, 148 W. River Street, Providence 1, Rhode Island (Electrodeposition)

SINZO OKADA, Department of Industrial Chemistry, Faculty of Engineering, Kyoto University, Yoshidamachi, Kyoto, Japan (Industrial Electrolytic and Theoretical Electrochemistry)

RALPH A. RUSCETTA, General Electric Company, mailing add: 11 Constitution Road, Pittsfield, Massachusetts (Electric Insulation and Industrial Electrolytic)

CONSTANTIN S. SZEGHO, The Rauland Corporation, 4245 North Knox Avenue, Chicago 41, Illinois (Fluorescent Materials)

ERNEST A. WINTER, Tennessee Corporation, mailing add: 509 E. Columbia Avenue, College Park, Georgia (Battery and Electrodeposition)

SECTION NEWS

Pittsburgh Section

The following members have been named as officers of the Pittsburgh Section of The Electrochemical Society:

Chairman—Eldredge K. Camp, Westinghouse Research Laboratories

Vice-Chairman—John M. Guthrie, Union Switch and Signal Company

Secretary-Treasurer—Massoud Simnad, Carnegie Institute of Technology

BOOK REVIEW

THE CHEMISTRY OF INDUSTRIAL TOXICOLOGY by H. B. Elkins. Published by John Wiley & Sons, Inc., New York, 1950. 406 pages, $5.50.

The author, as a physical chemist and Chief of Laboratory with the influential and well-known Division of Occupational Hygiene of the Massachusetts Department of Labor and Industries, is eminently qualified in this field. As the title states, the work is principally concerned with the chemistry of industrial toxicology rather than the biochemical or physiological aspects of the subject. The text fills the need for a comprehensive yet concise text which well deserves a place in the working library of chemists and chemical engineers who are in positions to specify and control chemical processes and who should always concern themselves with the toxicological aspects of these processes.

The text is well organized in general being in four sections. The first section discusses the avenues by which toxic substances are introduced into the body, the engineering approach to such problems, and the general methods used to detect toxic conditions in the worker.

The second part of the text systematically reviews more than 200 commonly used gases, elements, and compounds, both organic and inorganic. The information is arranged so that the consultation of any individual section is sufficient to give the reader a concise picture of the problem. One does not need to read other sections of the text in order to understand a spot reference. In all cases the information is presented first in tabular form, reducing all concentrations to mg/m³ or ppm, then followed by a brief discussion of the problem. In all cases references to pertinent publications for further consultation are made. In many cases the relation between the vapor pressures of metals at a variety of temperatures and the contamination of atmospheres resulting in mg/m³ are listed in tabular form. In certain cases the author offers his opinion of the general interpretation of the problem. These opinions are valuable to the nonprofessional toxicologist in assessing the facts in cases when conflicting evidence or conflicting allowable tolerances are listed. Too many similar texts quote results based on clinical tests with animals and do not or cannot translate their findings into

recommended practices. Most of the data are of the factory experience type.

The third part of the text reviews the industrial processes found to have the highest toxicological indices and includes preventative and detective procedures.

This section also includes a very useful table of Maximum Allowable Concentrations, including references for sources of the values. Values based on inadequate data are in parentheses. This table is followed by a discussion of controversial values and includes a chapter on widespread toxicological fallacies and unsolved problems in the field.

The fourth section of the book covers methods of collecting samples in a modern manner including descriptions of many easily constructed devices. The section finally includes analytical techniques, 98 pages, for the detection of materials ranging from acetone to zinc.

Of special interest to members of The Electrochemical Society are discussions of the hazards to be concerned with in degreasing, acid dipping, and electroplating. In this connection the author states, "The widespread employment of cyanide solutions in plating rooms without frequent fatal poisonings is a never ending source of wonder to industrial hygienists. . . ."

F. J. Biondi

RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

May 30, 1950

Gwynn, M. H., 2,509,921, Manufacture of Sponge Iron

Gillingham, S. W., 2,510,018, Electrolytic Humidostat

June 6, 1950

Bried, E. A., 2,510,063, Corrosion Inhibitor

Escoffery, C. A., and Hawk, W. H., 2,510,092, Rectifier

Miner, R. S. Jr., and Klekamp, L. E. Jr., 2,510,128, Method of Plating Metals with Zirconium

Richards, E. A., 2,510,141, Charging Secondary Electric Batteries

Johnson, H. V., and Stieber, H. C., 2,510,230, Electrode Joint

Shearer, R. E., 2,510,322, Selenium Rectifier

Addink, N. W. H., 2,510,361, Method of Producing Selenium Rectifiers

Kotterman, C. A., 2,510,588, Mounting and Connecting Device for Metal-Plate Rectifiers

Gale, A. J., 2,510,811, Piezoelectric Crystal

June 13, 1950

Russell, A. G., 2,511,128, Plating Rack

Richardson, D. E., 2,511,177, Apparatus for Measuring the Composition of a Gas

Baier, S. W., and Macnaughtan, D. J., 2,511,395, Process for the Electrodeposition of Tin Alloys

Koster, J., 2,511,507, Treating Manganese Electroplating Solutions

Schumacher, J. C., 2,511,516, Process for Making Sodium Chlorate

Smith, L. W., and Pingel, V. J., 2,511,551, Aluminum Alloys

Ellefson, B. S., 2,511,572, Luminescent Screen and Method of Manufacture

André, J., 2,511,686, Tank for Aqueous Electrolysis

Spina, J. A., 2,511,818, Photochlorination of Paraffinic Hydrocarbons

June 20, 1950

Vinal, G. W., 2,511,887, Battery Separator

Reed, L. G., 2,511,943, Storage Battery

Stareck, J. E., and Passal, F., 2,511,952,

Chemical Translations
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ELECTROLYTIC OUTFIT

For heavy duty industrial use directly on a.c. circuit by means of built-in rectifier

ELECTROLYTIC OUTFIT, Self Contained, Eberbach. With two independent units which can be operated simultaneously for deposition of nickel, copper, lead, antimony, cadmium, tin, zinc, chromium, etc. Designed for heavy duty industrial use directly on alternating current circuit by means of built-in selenium, full-wave rectifier. Delivers 8 volts, 5 amperes, d.c., at both spindles for two simultaneous determinations, or 10 amperes, d.c., for a single determination.

The stirrers are driven by a ball bearing, split phase, induction type motor at constant speed of 550 r.p.m. through a quiet V-belt drive. Hollow spindles with concealed spring clip are used for attachment of glass stirring rods, or Stainless steel holders for rotating electrodes.

4785-U.

Adjustable spring type, Stainless steel electrode holders replace the conventional chucks for the stationary electrodes; it is necessary only to depress the end of the holder to insert or release the electrode stem. The distance between the holders can be adjusted to suit the type and size of electrodes used.

The cabinet has heavy gauge Stainless steel front and cast aluminum end pieces which are covered with crystal black finish. The control panel contains two ammeters, range 0 to 10 amperes, and two voltmeters with range 0 to 10 volts on both sides of a central zero to indicate automatically the direction of current flow; two polarity reversing switches, separate switches for power and stirrer, fuses for a.c. and d.c., pilot lamp, and two knobs for adjustment of the carbon pile rheostats which control the amount of current flow to each unit.

Any type of platinum electrodes can be used.

Overall dimensions 29½ inches high × 14½ inches wide × 16½ inches deep.

4785-U. Electrolytic Outfit, Self Contained, Eberbach, as above described, with two glass stirring rods and 6 ft. rubber covered cord and plug, but without electrodes, glass beakers, electric heaters or electrode holders for rotating anodes. Maximum power consumption 400 watts. For use on 115 or 230 volts, 60 cycles, single phase, a.c. **395.00**

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Process of Plating Zinc on Aluminum

Wilson, H. D., 2,512,080, Battery Terminal Construction

Ma, C. C., and Offinger, M. W., 2,512,141, Coating Articles with Molybdenum

Dailey, H. J., 2,512,143, Electron Discharge Device Having a Radiator Integrated Therewith

Johnson, A. F., 2,512,157, Purification of Aluminum

Holden, A. F., and Conrad, A. G., 2,512,206, Electric Salt Bath Furnace

Froelich, H. C., 2,512,270, Method of Making an Improved Erythemal Phosphor

Hays, N. E., 2,512,328, Continuous Electroplating Device

Lindsay, A. R., 2,512,347, Dielectric Stencil

Lindsay, A. R., 2,512,348, Method of Making Dielectric Stencils

Conn, J. B., 2,512,483, Electrolytic Oxidation of Quinoline to Quinolinic Acid

Gide, R., 2,512,493, Treatment of Magnesium and Magnesium Base Alloys to Increase Their Resistance to Corrosion

Schneider, M. S., 2,512,554, Electroplating Rack

De Long, H. K., 2,512,563, Method of Electrolytically Coating Magnesium and Its Alloys

June 27, 1950

Hannon, A., 2,512,642, Apparatus for Electroprocessing Workpieces

Hull, R. O., 2,512,719, Electrodeposition of Tin

Westall, R. L., 2,512,757, Liquid Level Indicator for Storage Batteries and Other Liquid Containerss

Arbeit, P., 2,512,761, Electric Glass Furnace

Herzog, G., and Garrison, A. D., 2,512-773, Radiaoctive Measuring

Clark, F. M., 2,512,886, Dielectric Composition

Lieber, E., 2,512,949, Corrosion Inhibitor for Metals

Schumacher, J. C., 2,512,973, Process for Making Perchlorates

Gonze, M., 2,513,092, Photochemical Preparation of Benzene Hexachloride

Linkletter, H., and Van Kirk, W., 2,513,187, Silver Cleaner

Frasch, H. M. F., dit J., 2,513,237, Method of Protection of Magnesium and Magnesium-Base Alloys

Greig, H. G., 2,513,238, Dry Mixes for Use in Electrolytic Recording

Holst, G., and van Embden, H. J. M., 2,513,241, Nonemitting Electrode for Electric Discharge Tubes

NOTES FROM INDUSTRY

Products

KEPCO LABORATORIES, INC., Flushing, N. Y., has announced Model 315 Voltage Regulated Power Supply featuring one regulated B supply, one regulated C supply, and one unregulated

filament supply. Excellent regulation, low ripple content, and low output impedance distinguish this supply. Cabinet size is 16 x 8 x 8 inches.

The DEEMINIZER, a portable ion-exchange unit, which yields water equal in chemical quality to triple-distilled, is offered by the Crystal Research Laboratories Inc., Hartford. This low-cost unit operates by the new

mixed-bed technique of ion exchange and produces 10-million-ohm water for industrial or laboratory use. A built-in meter shows the purity of the output during operation.

BAUSCH & LOMB OPTICAL COMPANY, Rochester, N. Y., has developed a new series (E) of research microscopes and accessories that permit exhaustive study of a wide variety of specimens. Series "E" models have an inclined binocular body that can be interchanged with a graduated monocular draw tube for photomicrography, measuring, and other research applications. The draw tube is adjustable and graduated from 146 mm to 172 mm. Substages are also provided for routine, specialized, and most critical research.

Publications

AMERICAN CHEMICAL PAINT COMPANY, Ambler, Pa., has put out a new coating chemical selection chart which is available upon request.

WHAT'S NEW FOR THE LABORATORY—NUMBER 10, has been released by Scientific Glass Apparatus Company, Inc. of Bloomfield, N. J. This 24-page publication contains detailed descriptions with illustrations of many new or improved laboratory aids, including the Beckman automatic titrator, a U.S.P.-type tablet disintegration tester, balances, vacuum pumps, polarimeter, glassware, and other apparatus. Copy free upon request.

MATHIESON CAUSTIC SODA, a 48-page book, is now available to caustic users throughout the industry. It covers every phase connected with the manufacture, economics, properties, handling, and application of this product. Address requests to Mathieson Chemical Corporation, Mathieson Building, Baltimore 3, Md.

EMPLOYMENT SITUATIONS

Please address replies to box shown, % The Electrochemical Society, 235 West 102nd Street, New York 25, N.Y.

Positions Wanted

CHEMICAL ENGINEER, 31, B.S., W.P.I., three years' experience in electric reduction furnace operation and six years' electroplating in the electronic industry. Extensive background in all phases of metal finishing including industrial engineering aspects. Good appreciation of problems involved and teamwork required in design, plant layout, operation, maintenance, and quality control. Desires a responsible position in engineering or production development. *Reply to Box 342.*

PHYSICAL CHEMIST, Ph.D., with Master's degree in organic chemistry, seeks research or development position. Papers on corrosion, memberships in learned societies. No industrial experience, 4 years' teaching. *Reply to Box 343.*